Responsible Conduct of Research in Engineering: Addressing the America COMPETES Act

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Abstract

Recently, congress passed the America COMPETES Act. Among other things, this law mandates that the National Science Foundation (NSF) require responsible conduct of research (RCR) training for all trainees (undergraduate students, graduate students, and post-doctoral researchers) funded on NSF grants. The National Institutes of Health (NIH) have similar requirements for all trainees on training grants. To address these new requirements, universities across the nation are implementing RCR courses, online training tools, and other educational programs. However, the RCR materials and courses that exist have been primarily created for trainees in the biomedical sciences. For engineering students, the materials may not be fully appropriate as they do not address the full scope of engineering research work or the possible career pathways of engineering students. Courses and materials designed for engineering students need to be created to be able to engage and educate these students. In this paper, a course created in Fall 2007 for graduate students in engineering at the University of Kansas will be described. This course attempts to address the RCR training needs of engineering students by incorporating responsible conduct of research issues in research areas such as computational modeling and design and in career paths such as industry and government.

Introduction

The America COMPETES Act, which was signed into law Aug, 2007, increased research funding, but also contained mandates for those institutions seeking NSF funding. Specifically, in Section 7009 of the America COMPETES Act, the National Science Foundation was mandated to require responsible conduct of research (RCR) training for all trainees on NSF funded projects:

> "The Director shall require that each institution that applies for financial assistance from the Foundation for science and engineering research or education describe in its grant proposal a plan to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduate students, graduate students, and postdoctoral researchers participating in the proposed research project."[1]

The National Institutes of Health (NIH) had already had RCR training requirements for all participants in funded training, education and career development grants.

The author of this abstract was a participant in a National Academy of Engineering (NAE) funded workshop to develop recommendations for addressing this mandate.[2] This workshop came forward with a number of recommendations for providing effective RCR instruction to NSF trainees. These include:

1. Online training alone, without instructor guidance and/or discussion exercises, is less effective for student learning.
2. Training should focus both on developing moral reasoning skills and the application of these skills to a trainee's research work.

3. Materials need to be tailored to the level of the recipient (undergraduate through post-doctoral research).
4. Materials need to be tailored to the specific field of the recipient.
5. Multiple approaches are possible and can be combined beneficially.
6. PIs can be involved positively in the training.

In engineering, we have long had Accreditation Board for Engineering and Technology (ABET) requirements for undergraduate engineering ethics training. These requirements focus on engineers as practicing professionals working primarily in design and development rather than research. Undergraduate engineering curricula rarely cover topics typical of responsible conduct of research (RCR) such as paper authorship, peer review, and research funding management and rather focus on issues such as employer-client-employee relations, human health, safety and welfare in design, and intellectual property. Conversely, most responsible conduct of research courses and materials have been developed around the biomedical and clinical health sciences. At the graduate and post-doctoral level, responsible conduct of research and engineering ethics training for engineers has been less common outside of bioengineering. Unlike the biomedical sciences, engineering research and graduate work includes a wide range of activities and students in these programs have a wide range of career opportunities, not all of which are covered in traditional in a traditional RCR course. Therefore, in order to address the NSF mandate with courses appropriate to engineering students, it is critical that new materials and lesson plans be created.

Unique Elements of RCR for Engineering

Research

In the biomedical sciences, much of the research performed focuses on hypothesis-driven, laboratory or clinical research. As such, most of the focus in typical RCR courses is on this type of research. However, engineering graduate students do a variety of research activities including computational modeling, field testing, and design. In an ongoing survey of University of Kansas (KU) faculty, the faculty members were asked what research activities were performed in their laboratories. Of the 18 respondents, across 7 engineering disciplines, only 61% said their laboratories were engaged in hypothesis-driven experimental research. Conversely, 44% of these faculty members were engaged in observational experimental research, 39% were engaged in field testing, 44% were engaged in computational modeling, and 67% were engaged in design work. From this data, it is clear that an RCR course focused solely on hypothesis-driven experimental research will have less applicability to the students of 56% of our faculty.

There are a number of RCR topics that do apply to most of these areas of endeavor including authorship issues, plagiarism, confidentiality in peer review, and mentorship relationships. However, when one examines the research areas of computational modeling and design in particular, one can see there are a number of unique issues that exist in each of these types of research. In computation modeling, for example, mathematical models are created by making a number of physical assumptions such as “Newtonian Fluid” or “Rigid Body”. The appropriateness of these assumptions is very important to the validity of the model. Similarly, input data into a model can have error to which the model may or may not be sensitive. An understanding of this error and sensitivity is also important to the validity of the model. Such models are often solved using computational numerical methods. These methods, themselves, have limitations that are important to the validity of the model. Models often need to be validated against experimental data to demonstrate their accuracy in prediction of physical results. Finally, computation models are often presented using elaborate graphical representations. Misleading or inaccurate visualization of a model can lead observers to erroneous conclusions. All of these elements can factor into the quality of the modeling work, much in the same way that good data handling factors into the quality of experimental work.

In computational modeling, the work can sometimes seem far removed from a result that might impact human health and safety. However, there are a number of reasons one should still be concerned for the responsible conduct of research in computational modeling. First, computational modeling is used for purposes that can impact human health and safety. For example, computational modeling of weather and climate impacts the prediction of weather conditions such as hurricanes and the public policies on greenhouse gases. Computational modeling of a car structure may be used in the design of safety systems in the vehicle. Second, even when modeling does not directly impact human health and safety, models can impact scientific progress and irresponsible modeling efforts can lead to slowing of this progress to the detriment of the profession and our body of knowledge.

Like computational modeling, design in research also presents unique issues for responsible conduct courses. These issues include:

- Human health and welfare in the design of devices/ structures/constructs
- Global/social impact of engineering design
- Sustainability
- Issues in manufacturing (byproduct creation, pollution, energy efficiency)
- Intellectual property
- Confidentiality and classified/restricted research

These issues can be present in undergraduate engineering ethics classes, but often take on new meaning when a student's own design research is being considered. Reinforcement of these ideas at the graduate level can be important in advancing responsible conduct in this research area. In addition, students coming from other disciplines, countries, cultures or institutions may not have had the same exposure as undergraduates from one's home department.

Careers

In the survey of 18 engineering faculty members as KU, these professors were asked to describe where their MS and PhD students typically work after graduation. Interestingly, only 11% of these faculty reported their MS students end up working in academia and only 65% reported their PhD students end up working in academia. This compares to 100% who report their MS students are working in large companies and 77% who report their PhD students are working in large companies. (Figure 1) As one can see from this figure, many students end up working in industry, non-profits and government agencies. As such, a responsible conduct of research course that is focused on preparing students for their future careers should include topics related to such work. These topics can include business ethics, professional responsibilities, employer-employee interactions, intellectual property, military ethics, and public policy.

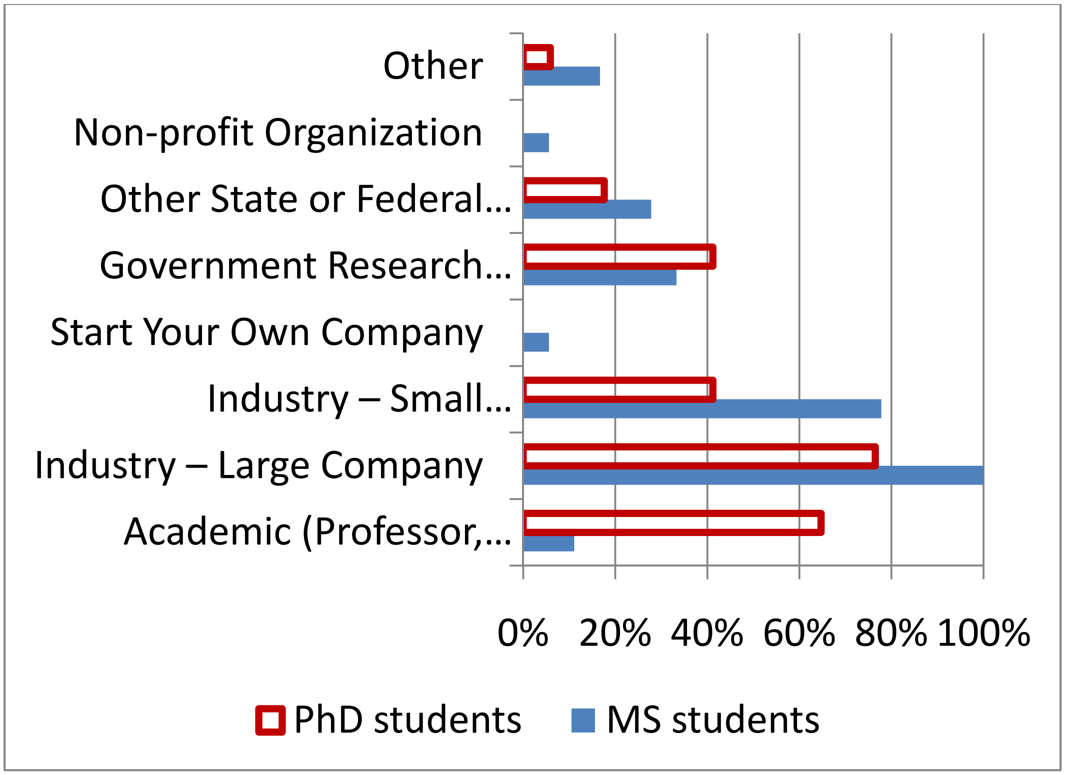

Figure 1. Survey of 18 engineering faculty members at KU. 100% of these professors reported their MS students work in industry and 77% reported their PhD students work in industry.

Responsible Conduct of Research in Engineering at KU

Beginning in Fall 2007, we have been teaching a 1-credit hour course each Fall in Responsible Conduct of Research in Engineering which meets for 1 hour each week. Originally created to meet the needs of Bioengineering graduate students (who are required to take it as part of their degree requirements), this course is open to all engineering graduate students. Mindful of the diverse research types and career trajectories of the students, this course includes a variety of engineering specific topics that are not typically found in RCR courses outside of engineering.

During the first week of the course, students are presented with a primer on moral reasoning including consequence-based reasoning (utilitarianism), duties/rights/justice-based reasoning (deontological), and virtue-based reasoning. Students are encouraged to see these philosophical principles as tools that can be used together and separately to assess ethical dilemma. These principles are presented with a step-by-step methodology of analysis which includes identifying stakeholders, identifying potential actions and consequences, examining stakeholders' duties, rights and virtues, and examining the actions based on the consequences, duties, rights and virtues. Students are also presented with an overview of the codes of ethics, societies, and federal agencies that guide the overall principles of responsible conduct.

During the next five to six weeks, the students examine topics of responsible conduct of research in scientific practice. These topics include:

- Best Practices in the Laboratory: Lab Notebooks, Data Handling, Fabrication/Falsification, Statistics,
- Working relationships: Advisor/Student, Colleagues,
- Papers and Conferences Presentations, Authorship Issues,
- Writing a Grant, Peer Review,
- Human and Animal Experimental Subjects, and
- Conflict of Interest

These sessions, and the sessions that follow are typically structure with short (10-15 minute) presentations followed by classroom discussion of case studies, contemporary issues, journal articles, or the results of preparatory homework assignments. Most weeks students are expected to do a preparatory assignment prior to coming to the class period.

The next six to seven weeks are focused on engineering practice and integration of research and engineering practice. The topics presented during this period include:

- Research with Industry and the Military: Issues in Confidentiality,
- Devices and Engineering Design,
- Intellectual Property, Copyright and Patenting,
- Professional and Business Practices,
- Engineering Modeling Issues,
- Social Justice and Sustainability, and
- Whistleblowing and Managing Issues.

Following a similar format to the scientific practice sessions, significant time is devoted to allowing students to discuss issues pertinent to the topic. For some topics, such as intellectual property, guest lecturers are brought in to provide their experience on the topic.

The final project for this class requires each student to create a case study based on what they have learned in the class and their own research and engineering experiences. Students work in teams to edit and analyze each other's cases. Students are required to write a commentary on their own case and their partner's case describing the ethical issues and possible ways to manage the issues using the methodologies described in the very first class.

This class has been taught for three years so far. In this time, a number of observations have been made. First, the class is most successful when students are able and willing to participate in the classroom discussions and talk about their own laboratory experiences. Second, including students' advisors in the discussion can be very powerful. One way to do this is to give students assignments that require them to ask questions of faculty and senior students. For example, one assignment in this class is to ask one's faculty advisor about their policy on authorship of papers. Faculty advisors have remarked that they appreciate this assignment as it opens up the sometimes awkward discussion of what is expected of students to be authors before authorship can become an issue in a laboratory.

Teaching this class has also lead to some revelations about the students that can be used to improve the class. The first revelation has been that we, as faculty, sometimes assume knowledge that is not fully present in our students. For example, in next year's class, I will be adding coverage of academic conduct and misconduct. In particular, students are not always as clear as we think they should be on what constitutes plagiarism. This course is also a place where academic conduct expectations and consequences for academic misconduct can be spelled out at the graduate level. With students coming from other disciplines, institutions, countries and cultures, this knowledge is not always uniform and a presentation of the expectations can be useful.

The second revelation is that engineering undergraduates, unlike science undergraduates, do not always have a strong background in hypothesis-driven experimental research or in academic research in general. Undergraduate engineering education contains some exposure to experimental work but these students are often not exposed to academic journal articles or to designing an experiment from scratch. Before talking about responsible conduct of such research, it is necessary, particularly with the first year graduate students in this class, to expose them to scientific practice.

Finally, the amount of material presented here is significant and difficult to cover in 15 hours of class time. It is difficult to cover any of these topics in great depth. As such, it is good to interface with instructors of other graduate courses and research advisors so that they can reinforce the material as it applies to their class or laboratory.

Conclusion

In conclusion, the America COMPETES Act mandates that all trainees on NSF funded research grants are trained in responsible conduct of research. NIH has similar requirements for trainees on their training grants. As such, many universities are now scrambling to provide RCR training to all their funded students. For engineering students, it is important to be aware of the breadth of their research and their career aspirations in order to design materials and courses that will engage these students and be relevant to their work. Unique topics such as professional engineering practice issues, business ethics, intellectual property, computational modeling issues and design issues should be included in any such training of engineering students.

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References

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Biographical Information

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Dr. Wilson is an Associate Professor in Mechanical Engineering at the University of Kansas and Director of the Bioengineering Graduate Program. She received her B.S. in Biomedical Engineering from Rensselaer Polytechnic Institute, her S.M. in Mechanical Engineering from Massachusetts Institute of Technology and her Ph.D. in Medical Engineering/Medical Physics from the Harvard-MIT Health Sciences and Technology Program. In addition to teaching a course in responsible conduct of research, she also teaches and does research in the use of control systems and dynamics to understand the human neuromuscular system and the etiology of musculoskeletal disorders.